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Evidence from Official Bank of Canada High-Frequency Data**

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Abstract: This paper analyzes official, high-frequency Bank of Canada intervention and exchange rate data (the latter quoted at the end of every 5-minute interval over every 24-hour period) over the January 1995 to September 1998 time-period. The data is of particular interest as it spans over two distinctly different intervention regimes – one characterized by purely rules-based (“mechanistic”) intervention versus one characterized by both rules-based and discretionary intervention. This unique feature of the data allows for both a comparison of the effects of rules-based versus discretionary intervention and a general investigation of intraday effects of intervention. Employing an event-study methodology and three different criteria for success, the study presents strong evidence showing that intervention systematically affects movements in the CAD/USD and in the desired direction along with some evidence that intervention is associated with a reduction of exchange rate volatility. Interestingly, there is no indication that discretionary intervention is more effective than rules-based intervention.

JEL Classification: E58, F31, G14, G15

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1. Introduction

The growing literature on foreign exchange rate market microstructure has made important contributions towards a better understanding of how exchange rate markets process and react to new information.¹ Furthermore, market microstructure models incorporating central bank intervention have advanced our understanding of how central bank intervention may affect exchange rates.² A common feature of the existing intervention literature, however, is the implicit assumption of a single underlying intervention strategy and a constant intervention regime.³

This paper adds to the empirical intervention literature by investigating whether rules or discretion matter for the effectiveness of intervention. The presented analysis employs official, high-frequency (intraday) data on Bank of Canada (BoC) intervention in the CAD/USD exchange rate market over the 1 January 1995 to 30 September 1998 time-period. This time-period spans over two distinctly different BoC intervention regimes. The data-set contains unique information on whether intervention operations were discretionary or carried out in accordance with a rules-based (“mechanistic”) policy framework. This feature of the data at hand facilitates both a comparison of the effects of rules-based versus discretionary intervention and a general investigation of intraday effects of intervention.

During the first regime, which ended on 11 April 1995, BoC intervention operations were very frequent as well as purely mechanistic. A CAD/USD exchange rate movement of a certain size would trigger intervention and, furthermore, appreciations and depreciations would generate the same response in absolute terms. On 12 April 1995, a new intervention program with both a mechanistic and a discretionary component was

¹ See Evans and Lyons (2002) and Lyons (2001) for important contributions.

² See, for example, Dominguez (2003a), Evans and Lyons (2001) and Pasquariello (2001).

introduced, thus allowing for more flexibility with respect to timing as well as with respect to magnitude of interventions.⁴ Accordingly, the data set allows for a distinction between interventions carried out under the pre- versus the post-April 1995 regime and, more importantly, between mechanistic and discretionary intervention operations.

The BoC is one of very few central banks to make the records of the intraday timing of its intervention operations available for the purpose of external research.⁵ However, the BoC data is not publicly available and so far only two internal studies (available as BoC working papers and discussed below) have investigated the high-frequency BoC intervention data. Both of these existing BoC high-frequency intervention studies focus exclusively on immediate volatility effects, and do so within a time-series analysis context. Consistent with Fatum and Hutchison (2006), and unlike the two existing studies of the BoC high-frequency intervention data, this paper investigates direction, smoothing, as well as volatility effects of BoC intervention over varying intraday window-lengths surrounding the intervention events and it does not employ a time-series framework for doing so.

Beattie and Fillion (1999) provide a time-series analysis of the intraday effects of intervention on the implied volatility of CAD/USD exchange rate options over the 12 April 1995 to 30 January 1998 period. They find that mechanistic intervention was widely anticipated by the market and had no impact on volatility, and some evidence that discretionary intervention was unanticipated and associated with a short-term decrease in

³ See Dominguez and Frankel (1993), Edison (1993), Humpage (2003), King (2003), and Sarno and Taylor (2001) for surveys of the intervention literature.

⁴ In September 1998, the BoC abandoned the mechanistic component and retained only the discretionary part. The BoC has not intervened in the CAD/USD market since 17 September 1998, which is also the last intervention day in the sample studied in this paper.

⁵ As noted by Dominguez (2003b), central banks rarely provide the exact timing of interventions or disclose how many intervention operations occurred over the course of a day. The BoC and the Swiss National Bank are exceptions.

volatility.⁶ In the second study using the high-frequency BoC intervention data, D’Souza (2002) incorporates both intervention data and data on BoC transactions aimed at replenishing reserves in order to test market microstructure hypotheses. He finds that foreign exchange traders treat an intervention operation as any other customer order and suggests that, in order to be effective, central banks must be able to forecast overall net customer trades at the time of intervention.

Two recent studies of official, high-frequency Swiss National Bank intervention data are of particular relevance to this study, both in terms of findings and methodology. Fischer and Zurlinden (1999) focus on (scaled) exchange rate changes measured between consecutive interventions and use an irregular time-series model as the foundation for their analysis. They find that only initial interventions matter while subsequent interventions are ineffective. In a recent contribution, Payne and Vitale (2003) extend the analysis conducted by Fischer and Zurlinden (1999). Within the context of an event study approach, they find evidence of a systematic link between intervention and both exchange rate returns and volatility. In particular, they show that intervention operations have short-run effects on the CHF/USD exchange rate lasting from 15 minutes to up to two hours following intervention. Payne and Vitale (2003) also find that intervention has a stronger impact when the Swiss National Bank moves with-the-market (“leaning with the wind”) and when its intervention is concerted with other central banks.

This study follows recent papers by Fatum (2000), Fatum and Hutchison (2003, 2006), Morel and Teiletche (2004), Payne and Vitale (2003) and others in employing an

⁶ These findings are consistent with Murray, Zelmer and McManus (1996), who analyze volatility effects of official daily BoC intervention data over a time-period covering both intervention regimes. For other daily data studies of BoC intervention see also Phillips and Pippenger (1993) and Rogers and Siklos (2003). These two external studies do not employ official BoC intervention data.

event study methodology for analyzing the effects of intervention on exchange rates.⁷ In this context of analyzing exchange rate movements around high-frequency intervention events, spot exchange rates quoted at the end of every 5-minute interval over a 24-hour period are investigated. Specifically, 5 through 120 minute windows around clusters of intraday intervention transactions are examined and, consistent with Fatum and Hutchison (2006), the effectiveness of intervention is assessed according to three different criteria for what may constitute effectiveness.

In addition, the paper takes into account the issue of currency co-movements. Currency co-movements are of potential importance to a study of this kind when the focus is on unilateral intervention conducted by a relatively small central bank and aimed at managing a minor currency vis-à-vis a major currency.⁸ In order to address the currency co-movement concern, the analysis of effectiveness is carried out on a “filtered” CAD/USD exchange rate as well as on the readily observable or “raw” CAD/USD rate. The “filtered” exchange rate measure is calculated as the difference between the percentage change in the (“raw”) CAD/USD rate and a weighted average of the percentage change in the GBP/USD, DEM/USD and JPY/USD exchange rates.

Dominguez (2003b) notes that, in contrast to studies of long-term effects of intervention, empirical studies of intraday effects of intervention generally find evidence that intervention matters. Consistent with her assessment, this study finds strong evidence in support of effectiveness when analyzing exchange rate returns (i.e. when focusing on the “direction” and the “smoothing” criteria of success) over the 5- through 120-minute windows. Additionally, the study finds some evidence that intervention is associated with

⁷ An event study is a very general test of a specific hypothesis and does not rely on a structural model of exchange rate determination. This is a desirable feature given the lack of consensus over the appropriate structural exchange rate model, but the drawback is that the particular channel of transmission (if intervention is effective) is not identified.

a reduction of exchange rate volatility, although it appears that the volatility effects are short-lived (only detectable within an hour after the intervention event) and not robust to adjusting for currency co-movements.

Contrasting the results of the analysis of rules-based events with the results of the analysis of the discretionary events does not suggest that discretionary intervention is more effective than rules-based intervention. In fact, the CAD/USD exchange rate market appears to react the same way to frequent and anticipated interventions as it does to infrequent and unanticipated intervention. This is an interesting and unexpected finding. Although the event study methodology does not identify a specific channel through which intervention works, if effective, this result seems to indicate that intervention has a price impact through the (micro) portfolio-balance channel rather than through signaling. As such, the finding that rules-based intervention appears no less effective than discretionary intervention appears in line with the order-flow analysis presented in Evans and Lyons (2001).

The rest of the paper is organized as follows. The next section provides an overview of institutional aspects of BoC intervention pertaining to the period under study. Section 3 presents the data. Section 4 discusses the event study methodology and the criteria for assessing effectiveness. Section 5 presents the results and section 6 concludes the paper.

2. Institutional Aspects

The BoC intervenes in the CAD in its capacity of fiscal agent for the Government of Canada. In order to do so, the BoC uses the Government's foreign exchange reserves, held in the Exchange Fund Account. In accordance with the Canadian Currency Act,

⁸ Canada is a small, open economy with spot turnover in its currency representing about 2% of

foreign exchange reserves may be used to protect the external value of the monetary unit of Canada. With respect to foreign exchange intervention, this mandate has been interpreted to mean maintaining an orderly market for the CAD, i.e. BoC intervention is aimed at smoothing (intraday) movements of the exchange rate and providing liquidity to the foreign exchange market when needed.

BoC intervention in the CAD/USD exchange rate market is unilateral (in particular, the US Fed is not intervening in the CAD/USD market) and characterized as “leaning against the wind” in the sense that CAD are bought (sold) when the CAD depreciates (appreciates) against the USD. All BoC intervention operations are sterilized on a daily basis.

During the 1995 to 1998 period, intervention in the CAD/USD exchange rate typically took place during North American market hours from 8:00 a.m. to 4:00 p.m. EST, with some instances of intervention continuing overnight during European market hours.⁹ Intervention was passive, with the BoC leaving offers to buy and sell CAD rather than hitting bids.

The period under study features two distinct intervention regimes. A rules-based regime characterized by a mechanical – and therefore predictable – response to exchange rate movements was in place until 12 April 1995. During this regime, the BoC determined when to intervene by monitoring a 100-basis point “non-intervention” band. When the exchange rate breached one end of this band, intervention operations (in terms of USD purchases or sales against CAD) were conducted at pre-set levels of intensity, with intensity measured by the amount of intervention that occurred for each basis point change in the CAD/USD. The standard amount was CAD 4 million per basis point. The

total daily average foreign exchange turnover during the time-period under study (BIS 1999).

non-intervention band was dragged or “ratcheted” in the direction that intervention occurred according to the amount and intensity of the most recent intervention operation. Under this mechanistic framework, intervention was persistent and would continue until the CAD/USD reversed direction and moved back inside the non-intervention band. As a result, the BoC intervened on average on almost every other business day during this regime. Intervention during this period was typically conducted directly with dealers at the major chartered banks who were instructed to keep the intervention activity secret.

On 12 April 1995, a revised intervention regime was introduced. It was designed to increase the effect of intervention by reducing its frequency, increasing its magnitude, allowing for more discretion with respect to its timing, and raising the visibility when it occurred. The change in intervention policy followed a major review of the purely mechanistic intervention regime and reflected the growth of the currency markets as well as the state of the academic literature on intervention.¹⁰

Under the revised regime, the non-intervention band was widened to 140 basis points and was rebased daily around the 4:00 p.m. EST North American closing exchange rate. The daily rebasing reduced the frequency of intervention to less than 10% of business days by 1996, as the currency would have to move by 70 basis points in either direction following rebasing before new intervention would occur. The visibility of intervention was increased by increasing the standard intensity of intervention to CAD 8

⁹ If the currency continued to move in one direction at the end of the North American trading hours, the BoC would leave instructions with a European agent, typically the Bank of England, in order for the agent to carry out intervention on behalf of the BoC.

¹⁰ The BoC addressed the change in a letter sent to foreign exchange market participants on 5 April 1995: “[The] conclusions of this work support the idea that foreign exchange market intervention is most useful when used as a signaling tool. Our analysis of the current intervention techniques we use is that they are not as effective as they could be in this regard. This is largely because the frequency of our intervention tends to reduce the “newsworthiness” of the fact that we are in the market. Also, given the volumes in today’s market, the intensity of our current intervention probably adds little in terms of enhancing market liquidity.” (Letter from Don Stephenson, Associate Adviser, Bank of Canada.)

million per basis point. Furthermore, intervention was primarily conducted through foreign exchange brokers, who were instructed to announce BoC intervention as soon as the first transaction of the day had been completed.

Finally, the revised framework introduced greater discretion, although mechanistic elements were maintained. The wider non-intervention band continued to be dragged up or down intraday in response to each intervention operation. However, the timing of intervention could be varied to allow the BoC to intervene earlier and with greater intensity in response to what were believed to be destabilizing movements of the exchange rate. During such turbulent periods, the non-intervention band could be reset at half the distance from its normal setting, allowing the BoC to intervene sooner, and the intensity of intervention could be increased as the situation demanded. A decision to reset the band in this fashion was initiated by the BoC and authorized by the Department of Finance.

See Chiu (2003), D'Souza (2002), and Murray, Zelmer, and McManus (1996) for additional details on the BoC intervention framework during the 1995 to 1998 period. See also Neely (2001) for an interesting paper on intervention practices based on survey responses from 22 monetary authorities, including the Bank of Canada.

3. Data

This study uses non-public, high-frequency (intraday) intervention data, provided by the BoC. The data set contains information on each individual intervention transaction, including the date, the time and the transaction size.¹¹

During the full sample period, 2 January 1995 to 30 September 1998, the BoC carried out 1530 intervention transactions (on a total of 151 intervention days). Of these

transactions, 371 (on a total of 40 intervention days) took place during the intervention program that ended on 11 April 1995.¹²

The individual intervention transactions ranged in magnitude from USD 2 million to USD 138 million, with an average amount of USD 18 million and a median amount of USD 20 million.¹³ On intervention days, an average of 21 transactions occurred, with the number of transactions ranging from a low of one to a high of 83 (on 7 August 1998). The amount traded on intervention days ranged from USD 5 million to USD 1.2 billion, with a mean of USD 380 million and a median of USD 300 million

Table 1 provides an overview of the high-frequency intervention data-set. It shows that a total of 694 intervention transactions were discretionary while the remaining 836 transactions were carried out in accordance with the mechanistic policy framework. Table 1 also shows that the number of interventions that occurred due to a mechanical rebasing of the non-intervention band dominated in 1995, while the number of discretionary interventions increased steadily from 1996 and onwards. Additionally, the table shows that the number of purchases and sales were largely balanced in 1995, while the ratio of purchases to sales increased dramatically over the following years.

The analysis relies on high-frequency exchange rate data purchased from Olsen and Associates. This data provides the spot exchange rate at the end of every 5-minute interval over a 24-hour period for the CAD/USD, DEM/USD, GBP/USD and JPY/USD

¹¹ Since the intervention data set is not publicly available, the paper is not displaying or describing the intervention magnitudes in great detail.

¹² The starting date of the sample is determined by data availability, as the BoC has not maintained records of intraday intervention transactions prior to January 1995.

¹³ Individual transaction magnitude may contain limited information as intervention transactions conducted through foreign exchange brokers were often bundled together to reduce the number of individual trade “tickets”. The event study methodology employed in this study does not rely on information regarding transaction size and uses bid/ask rates rather than transaction prices in order to facilitate the investigation of exchange rate movements across different window lengths.

exchange rates.¹⁴ The evolution of the intervention variable against the CAD/USD exchange rate is displayed in Figure 1. Figure 2 shows the CAD/USD juxtaposed against an equally-weighted basket of the DEM, the GBP and the JPY vis-à-vis the USD, with all exchange rates indexed to 100 at the beginning of the sample period.

4. Methodology

The starting point for an event study is to define the event of interest and to identify the periods over which the security price is examined (the “event windows”). In this context, the event is defined as a cluster of intervention transactions and the event windows are the pre- and post-event minutes during which the CAD/USD exchange rate movements are analyzed.

Specifically, an event is defined as a cluster of individual intervention operations in the CAD/USD exchange rate market in one direction (in terms of purchases or sales), interspaced by at most 30 minutes of no intervention operations (the “tranquility” period that can be allowed for while still considering the surrounding intervention transactions to be part of one and the same event). Given the frequency and structure of the intervention data at hand, we adjust the methodology of Fatum (2000) and Fatum and Hutchison (2003, 2006) to accommodate the analysis of intervention data captured at this higher frequency, and employ a “tranquillity” period of 30 minutes for our baseline results (and vary this number in the robustness checks). Consistent with the high-

¹⁴ The bid and offer rates are provided for intervals where an actual trade takes place, while a representative quote is used for other periods. There is little time-variation in the bid-ask spreads and the analysis focuses on the bid rates.

frequency analysis presented in Payne and Vitale (2003), pre- and post-event window lengths of 5 through 120 minutes are applied.¹⁵

As noted by, for example, Dominguez and Frankel (1993) there is no convention on what constitutes successful intervention. This analysis follows Fatum and Hutchison (2006) and applies their three alternative criteria of success. The first criterion of success is simply whether the direction of the movement in the exchange rate is the same as the direction in which the BoC was intervening, e.g. does the value of the CAD relative to the USD increase after CAD are purchased? This measure of successfulness is referred to as the “direction” criterion and is formally expressed as follows: An event is a success if either

$$\{E_i > 0 \text{ and } \Delta s_{i+} > 0\} \text{ or } \{E_i < 0 \text{ and } \Delta s_{i+} < 0\}$$

where E_i is the total amount of central bank intervention (positive values represent purchases of USD, negative values represent sales of USD) during event i and Δs_{i+} is the CAD/USD exchange rate change (in percent) during the associated post-event window.

As previously noted, the stated motivation for BoC intervention is to maintain orderly markets, suggesting that intervention operations are carried out for the purpose of smoothing exchange rate movements or reducing exchange rate volatility, rather than for affecting the direction of exchange rate movements. The next two effectiveness criteria assess whether the BoC succeeded in accordance with the stated purpose of intent.

The second criterion defines a successful event as one where intervention is associated with a smoothing of the exchange rate movement. This criterion is formally

¹⁵ Additionally, the window lengths are not expanded beyond 120 minutes in order to eliminate instances of pre- and post-event window overlaps.

expressed as follows: An event is a success according to the “smoothing” criterion if either

{the event is a success according to the “direction” criterion} or

$$\{E_i > 0 \text{ and } \Delta s_{i+} > \Delta s_{i-}\} \text{ or } \{E_i < 0 \text{ and } \Delta s_{i+} < \Delta s_{i-}\}$$

where Δs_{i-} is the CAD/USD exchange rate change (in percent) during the associated pre-event window.

The third criterion of success compares the (realized) variance of the CAD/USD exchange rate preceding and succeeding each event, respectively, and associates reduced volatility after relative to before the event with success. This criterion is formally expressed as follows: An event is a success according to the “volatility” criterion if

$$\{\sigma_{i+}^2 < \sigma_{i-}^2\}$$

where σ_{i+}^2 (σ_{i-}^2) denotes the realized post-event variance (pre-event variance) of the CAD/USD exchange rate. More specifically, the high-frequency exchange rate data is used for calculating the variance of the CAD/USD exchange rate during the 30, 60, 90 and 120 minutes preceding and succeeding each event in order to facilitate the comparison of volatility patterns around each of the events.

Three statistical tests are employed. The main test is the non-parametric sign test for the median. This test verifies whether the observed number of successes based on the “direction” (appreciation or depreciation), the “smoothing” (appreciation/smaller depreciation or depreciation/smaller appreciation), and the “volatility” (decreased or not) criteria are random or systematic.

With reference to the “direction” criterion for success, the null-hypothesis is that the probability of observing a positive value (“success”) is the same as that of observing a negative value (“no-success”), hence the underlying probability parameter is 0.5. In other words, the random variable X (equal to the number of positive values or “successes”) among n sample observations has a binomial distribution with $\mu = 0.5$. A significant sign test indicates that the observed number of successes is not a random finding attributable to the equal probability of appreciation or depreciation. For details on this test in event studies, see MacKinlay (1997).¹⁶

It should be noted that the BoC interventions are always leaning against the wind (e.g. the BoC purchases CAD in response to a CAD depreciation), thus the “true” probability of observing a reversal of the exchange rate movement around periods of intervention (under the assumption that intervention has no effect) is likely to be less than 0.5. Therefore, a probability parameter choice of 0.50 (0.75) when assessing effectiveness according to the “direction” (“smoothing”) criterion constitutes a conservative parameter value that tends to bias the results towards *not* finding significant effects of intervention. Put differently, it literally raises the bar with respect to the number of successes necessary for rejecting randomness.¹⁷

In addition, the non-parametric rank test and the matched sample (difference-in-means) tests are employed. The matched sample test is only associated with the “smoothing” criterion as it indicates, at the minimum, smaller post-event CAD

¹⁶ See Fatum (2000) for a discussion of the choice of probability parameters associated with the “direction” and the “smoothing” criteria for success and Fatum and Hutchison (2006) regarding the “volatility” criterion.

¹⁷ This is indeed confirmed when calculating the probability of observing a change in the direction of the CAD/USD exchange rate and the probability of observing a smoothing over the sub-sample of observations that were not part of any of the events as a control sample, as suggested by Fatum (2000). For example, when focusing on the 10-minute window length, the “unconditional” probability of observing a “direction” (“smoothing”) success over the full 1995 – 1998 time-period is 0.483 (0.693).

depreciation or appreciation. Since both additional tests confirm the results based on the sign test, only sign test results are reported.¹⁸

4.1 Currency Co-Movements

Eun and Lai (2004) point out that despite the vast research in co-movement of other asset prices such as bonds and stocks, the issue of currency co-movement has not been given much attention in the academic literature. They document systematic co-movement patterns across several currencies, in particular vis-à-vis the USD and to a lesser extent vis-à-vis the EUR, and they present evidence that currency co-movement is significantly driven by “the competitive influence” of major currencies on minor ones.

Currency co-movements are also of potential importance to the analysis of effectiveness of intervention, in particular when focusing on unilateral intervention conducted by a minor central bank and aimed at managing a minor currency vis-à-vis a major currency. To illustrate this point, suppose an appreciation of the CAD against the USD follows a BoC intervention event characterized by CAD purchases. The event will then appear effective according to the “direction” criterion described above. However, if the USD is depreciating against not just the CAD but against other currencies in general, there is little reason to believe that the USD depreciation should be ascribed to the unilateral BoC intervention transactions.

In order to make an attempt at addressing this concern, the analysis of effectiveness is carried out on a “filtered” CAD/USD exchange rate as well as on the readily observable or “raw” CAD/USD rate. The “filtered” exchange rate measure is calculated as the difference between the percentage change in the (“raw”) CAD/USD rate

¹⁸ For details on the rank test in event studies, see Cambell and Wasley (1993) and MacKinley (1997). See, for example, Ben-Horim and Levy (1984, p. 458) for details on the matched sample test and Fatum and Hutchison (2003, 2006) for applications.

and a weighted average of the percentage change in the GBP/USD, DEM/USD and JPY/USD exchange rates.¹⁹

4.2 Intraday Seasonal Volatility Patterns

It is known that high-frequency exchange rate data display intraday seasonal volatility patterns (see, for example, Andersen and Bollerslev 1998 and Andersen, Bollerslev and Das 2001). Therefore, assessing the impact of intervention in accordance with the “volatility” criterion could lead to false conclusions unless intraday seasonality in the CAD/USD is accounted for. In order to address this concern, the analysis follows Beattie and Fillion (1999) and captures the intraday patterns using a Flexible Fourier Form (FFF) with a seasonality parameter of 3 (thus allowing for three seasonality cycles within each 24-hour period). In fact, the exact same FFF as described in detail by Beattie and Fillion (1999, p. 8-9) is used, except that the FFF estimations of this paper employ 5-minute rather than 10-minute exchange rate quotes and, therefore, doubles the number of intervals per day.

A second estimation of intraday volatility patterns includes to the FFF a dummy variable that controls for time-intervals coinciding with intervention transactions. This dummy variable is included to address the possibility that intraday exchange rate volatility is abnormally high when intervention occurs.²⁰ In the context of a time-series analysis of the impact of intervention on volatility, inclusion of the intervention dummy in the FFF estimations would be very problematic not only because of (additional) potential simultaneity bias but because the intervention variable itself is subsequently

¹⁹ As a robustness check, different weights are used for calculating the “filtered” exchange rate. The findings, however, show only little variation across the range of weight combinations and, therefore, only the results based on equal weights are reported.

²⁰ Fischer (2003) finds that intraday exchange rate volatility is almost three times higher on intervention days.

used as an explanatory variable when modeling the seasonally adjusted volatility. However, this is not a concern in this event study analysis where the focus is on exchange rate behavior before and after the intervention events, i.e. when no intervention occurs.

As it turns out, whether effectiveness of intervention is assessed according to the “volatility” criterion using the CAD/USD exchange rate without adjusting for seasonality of intraday volatility patterns or using either of the two adjustments described above, identical conclusions are reached. The volatility results discussed in detail in the next section are based on the exchange rate series that have not been adjusted for seasonality.

5 The Results of the High-Frequency Event Study

Using the baseline event definition that allows for a maximum of 30 minutes of no-intervention while still considering the surrounding intervention transactions to be part of one and the same event, 321 separate BoC intervention events are identified, 270 of which occurred within market hours (EST). While the timing of the intervention transactions carried out within market hours is recorded by the BoC (and provided with the intervention data), this is not the case for the transactions that took place outside of North American market hours. Therefore, in order to fully utilize the knowledge of the timing of intervention transactions and, subsequently, the timing of the events, the analysis focuses on the 270 events that took place within market hours.

By construction of the event definition itself, each event is characterized as either a CAD purchase or a CAD sale event and, furthermore, each event is well-defined with respect to the timing of start and finish. Therefore, for each event it is straightforward to calculate the associated pre- and post-event exchange rate changes and volatilities separately for each of the 24 different window lengths (5 through 120 minutes). This, in

turn, enables the analysis to classify each event as successful or not according to each of the three criteria for success, separately across each of the 24 windows lengths.

5.1 Direction Results

Figure 3 displays the results from the sign test based on the “direction” criterion with the underlying probability parameter of 0.50 across all window lengths (5 through 120 minutes).²¹ For all figures 3.1 through 3.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95 percent significance level. Figure 3.1 summarizes the findings based on all 270 events and the “raw” CAD/USD exchange rate while figure 3.2 summarizes the findings based on the same 270 events and the “filtered” CAD/USD rate.

All the bars in figure 3.1 reach or exceed the horizontal line (at 150 successes out of 270), thus the null hypothesis that the observed number of successes is random is rejected (separately) for each window length. Put differently, the results displayed in figure 3.1 provide strong evidence that BoC intervention is associated in a highly significant and systematic way with intraday movements in the CAD/USD exchange rate.

Turning to the analysis of the “filtered” exchange rate and figure 3.2, the findings of significance at the 95 percent level are repeated for window lengths of one hour or less while the longer window lengths are, at a minimum, associated with significance at the 90 percent level. For both figures 3.1 and 3.2 is it the case that the significance levels tend to drop as the window length increases.

As noted earlier, the sample period under study is of particular interest as it comprises two different intervention regimes, the first characterized by mechanistic intervention and the second characterized by both mechanistic and discretionary

intervention. In order to investigate whether mechanistic and discretionary intervention events affect the market differently, the analysis is re-done separately on the sub-sample of events associated with mechanistic intervention and separately on the sub-sample of events associated with discretionary intervention.²²

Figures 3.3 and 3.4 show the results of the analysis of the 145 mechanistic events using the “raw” CAD/USD and the “filtered” CAD/USD exchange rate, respectively. Both figures repeat the patterns displayed for the full samples, i.e. when focusing on the “raw” exchange rate, intervention is significant at the 95 percent level across all window lengths while intervention is significant, at a minimum, at the 90 percent level when looking at the “filtered” exchange rate.

Figures 3.5 and 3.6 show the results based on the discretionary events. Again, for almost all window lengths of one hour or less is it the case that the null hypothesis of randomness is rejected at the 95 percent significance level (at 73 successes or more out of 125). Somewhat surprisingly, there is no indication that discretionary intervention is, on average, associated with stronger effects than mechanistic intervention. In fact, when focusing on the window lengths that are longer than one hour there is not a single instance of significant effects of discretionary intervention at the 95 percent level and this is in contrast to the findings based on the sub-sample of only mechanistic events.²³ The previously observed pattern of lowered significance levels as the window lengths are expanded is repeated.

²¹ Due to the non-public nature of the BoC intervention data, the intervention volumes and the exact timing of events are not displayed.

²² Events containing both mechanistic and discretionary intervention transactions are classified as discretionary. Alternatively, dropping these “mixed” events from the analysis does not affect the results.

²³ It is noteworthy that the difference in sample sizes when comparing significance across mechanistic and discretionary events leads to different degrees of freedom of the sign test and, furthermore, that the success-to-failure ratio is very similar across the two sub-samples.

In sum, the analysis based on the “direction” criterion of success shows that BoC intervention is significantly associated with intraday movements in the CAD/USD exchange rate and that the effects of intervention appear to be the strongest when window-lengths of one hour or less are considered. Furthermore, the results imply that BoC intervention has a very similar intraday impact on the CAD/USD exchange rate regardless of whether the intervention events are rules-based or discretionary.

5.2 Smoothing Results

Figure 4 displays the results based on the “smoothing” criterion and the sign test with the underlying probability parameter of 0.75 across all window lengths. Figures 4.1 and 4.2 summarize the findings based on all 270 events and the “raw” CAD/USD and the “filtered CAD/USD exchange rate, respectively. The observed number of successes is, of course, higher than the observed number of successes according to the “direction” criterion, by construction of the “smoothing” criterion that embodies the “direction” criterion; similarly, so is the number of successes necessary in order to reject the null hypothesis of randomness. Both figure 4.1 and 4.2 show patterns very similar to the corresponding “direction” figures (figures 3.1 and 3.2) and repeat the findings of significance at the 95 percent level for all window lengths when focusing on the “raw” exchange rate measure while the longer window lengths for both the “raw” and the “filtered” rate are associated with significance at the 90.

Figures 4.3 and 4.4 (figures 4.5 and 4.6) display the results based on the 145 (125) mechanistic (discretionary) events and the findings are very similar to those based on the “direction” criterion. In particular, there is once again no indication whatsoever that discretionary intervention is more effective than mechanistic intervention.

Furthermore, figure 4.6 shows that there are no significant effects of discretionary intervention at the 95 percent level when focusing on the “filtered” exchange rate.

5.3 Volatility Results

Figure 5 displays the results from the comparison of pre-event versus post-event volatility across window lengths of 30, 60, 90, and 120 minutes. In this context, the sign test determines whether the observed number of events associated with decreased CAD/USD volatility is random or systematically associated with intervention events. Consistent with the volatility analysis in Fatum and Hutchison (2006), the test has an underlying probability parameter of 0.50 thus the horizontal 95 percent significance lines for all figures 5.1 through 5.6 are (pair wise) identical to the significance lines for the sign test results of the “direction” criterion, as displayed in figures 3.1 through 3.6.

Focusing first on the analysis using the “raw” exchange rate, figures 5.1, 5.3 and 5.5 all show that the number of events associated with decreased post-event volatility is high enough to reject randomness at conventional significance levels when 30 and 60 minutes window-lengths are investigated while the number of successes according to the “volatility” criterion is too small to question randomness when the window-lengths are expanded. In other words, the volatility effects of intervention are significant but short-lived in the sense that the effects are only detectable when comparing exchange rate movements within one hour before and after the events. This appears to be the case regardless of whether the sub-samples of mechanistic and discretionary intervention are analyzed separately or whether all the events are analyzed jointly.

Turning to the “filtered” exchange rate and the results displayed in figures 5.2, 5.4 and 5.6, the pattern regarding lower significance levels as the window-lengths are expanded is repeated. For the analysis using the “filtered” exchange rate, however, none

of the window lengths are associated in a highly significant and systematic way with intraday CAD/USD exchange rate volatility (none of the bars reach the horizontal 95 percent significance line), implying that the effects of intervention on volatility patterns within the first two hours around the described events are less robust than the effects of intervention on “discretion” and “smoothing”.²⁴

5.4 Monetary Policy Changes and USD Intervention by Other Central Banks

As mentioned by Fatum and Hutchison (2003) and others, the event study methodology assumes that intervention defines the event and is not systematically related to other relevant economic news such as monetary policy changes or USD intervention by other central banks.

In order to address this concern, the analysis of sections 5.1 through 5.3 is also carried out on sub-samples of events that do not occur on days coinciding with a monetary policy change in either Canada or the United States. Table 2 shows that there are only 13 days over the full sample where BoC intervention coincided with a BoC change of the target for the overnight interest rate. There are no cases of BoC intervention coinciding with changes in US monetary policy. The results described above are robust to the exclusion of the high-frequency events occurring on days when the BoC changed monetary policy.

Intervention in the DEM/USD or the JPY/USD exchange rate markets by other major central banks coincides with 4 days of BoC intervention. Dropping the associated high-frequency events from the analysis does not impact the results.

²⁴ Some studies find that intervention is systematically associated with increased volatility (see Galati, Melick and Micu, 2005, for a recent discussion) and, therefore, the analysis also tests for this possibility. However, the observed number of events associated with increased volatility is random across all window lengths (30, 60, 90 and 120 minutes).

As a methodological robustness check, the baseline event definition is changed and the analysis of sections 5.1 through 5.3 redone. Specifically, an event is redefined as a cluster of individual intervention operations in one direction, interspaced by at most 60 (instead of 30) minutes of no intervention operations. Using this altered event definition, 220 (instead of 270) within market hours events are identified. The analysis of these 220 events, including separate analyses of mechanistic and discretionary events, reaches identical conclusions as the analysis based on the 270 baseline events.

6 Conclusion

This paper investigates the effectiveness of sterilized intervention in the CAD/USD exchange rate from 1995 to 1998, using official intervention data provided by the BoC. The time period under study covers two different intervention regimes – an earlier mechanistic regime where intervention was frequent and widely anticipated, and a revised regime that introduced discretion on the timing and intensity of intervention. The data set consists of high-frequency (intraday) data with information on the timing of each intervention transaction and, importantly, the data contains unique information on whether intervention operations were discretionary or carried out in accordance with the rules-based (“mechanistic”) policy framework.

The analysis uses an event study framework and different criteria of success for investigating the effects of intervention on exchange rates, and controls for currency co-movements by carrying out the analysis on a readily observable or “raw” CAD/USD exchange rate as well as on a “filtered” CAD/USD exchange rate.

Consistent with the general assessment of Dominguez (2003b) regarding empirical studies of intraday effects of intervention and consistent with the results of Payne and Vitale (2003), this study provides strong evidence in support of effectiveness

when analyzing exchange rate returns (i.e. when focusing on the “direction” and the “smoothing” criteria of success) over the 5- through 120-minute windows. Additionally, the study finds evidence that intervention is associated with a relatively short-lived reduction of exchange rate volatility.

Contrasting the results of the analysis of rules-based events with the results of the analysis of the discretionary events does not suggest that discretionary intervention is more effective than rules-based intervention. Although the event study methodology does not identify a specific channel through which intervention works, if effective, this result seems to indicate that intervention is not working through the signaling channel. Instead, this finding seems consistent with the order-flow analysis presented in Evans and Lyons (2001), in which it is shown that sterilized intervention that is unannounced and not associated with a monetary policy signal has significant portfolio-balance price effects.

It is important to note that the presented analysis concerns short-term effects of intervention and, therefore, the conclusions do not pertain to long-term effects. In a general modeling framework, Dominguez (2003b) illustrates this point nicely. She expands the model by Bacchetta and van Wincoop (2003) to include interventions and shows that only those interventions that provide information about future fundamentals should be expected to have long-term effects while interventions providing only “non-fundamentals” information may potentially exacerbate non-fundamentals driven exchange rate movements in the short run. In other words, her analysis illustrates and offers an explanation for why the short-run effects of intervention may differ from its long-run effects. In keeping with this point, additional work is needed in order to address the issue of long-run effects and associated policy implications of BoC intervention.

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Figure 1: Intervention in the CAD and the CAD/USD rate

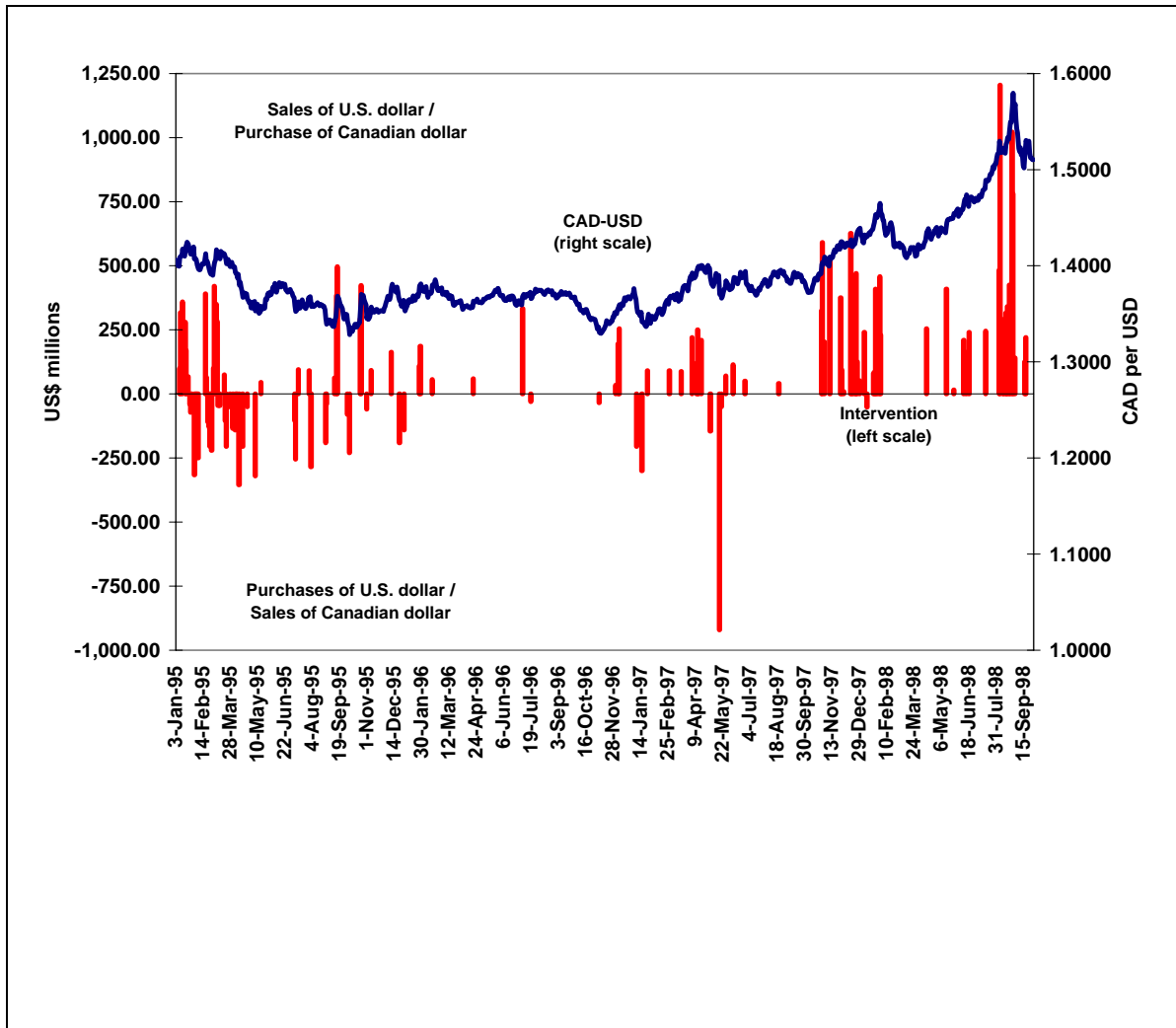


Figure 2: Index of CAD versus Net Change in Basket of DEM, JPY and GBP (1 January 1995 = 100)

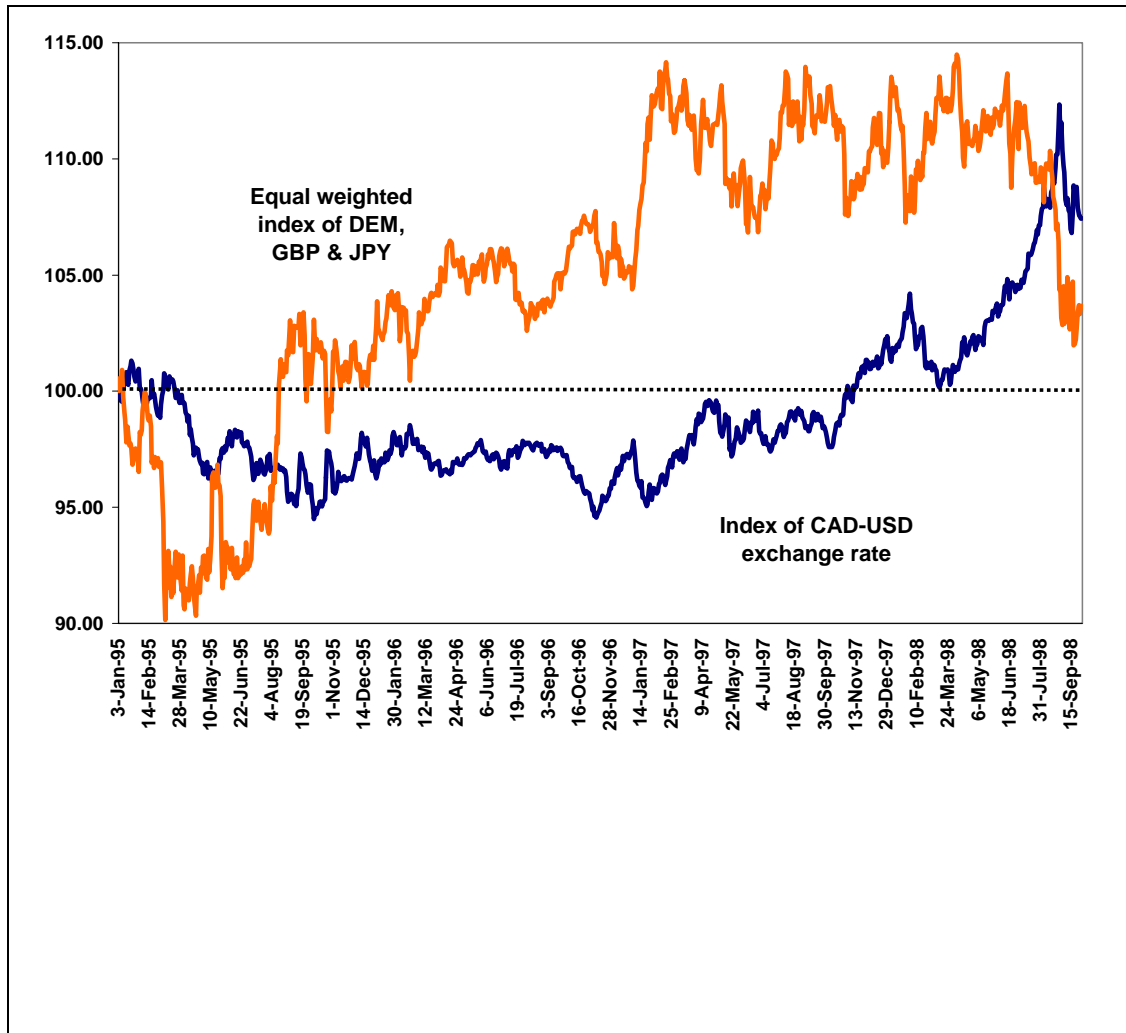


Figure 3: Success of Intervention Based on “Direction” Criterion

This figure displays the results of the sign test based on the “direction” criterion with the underlying probability parameter of 0.50. Intervention is a success when the CAD/USD rate moves in the direction consistent with the intervention event. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all figures 3.1 through 3.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95 percent significance level.

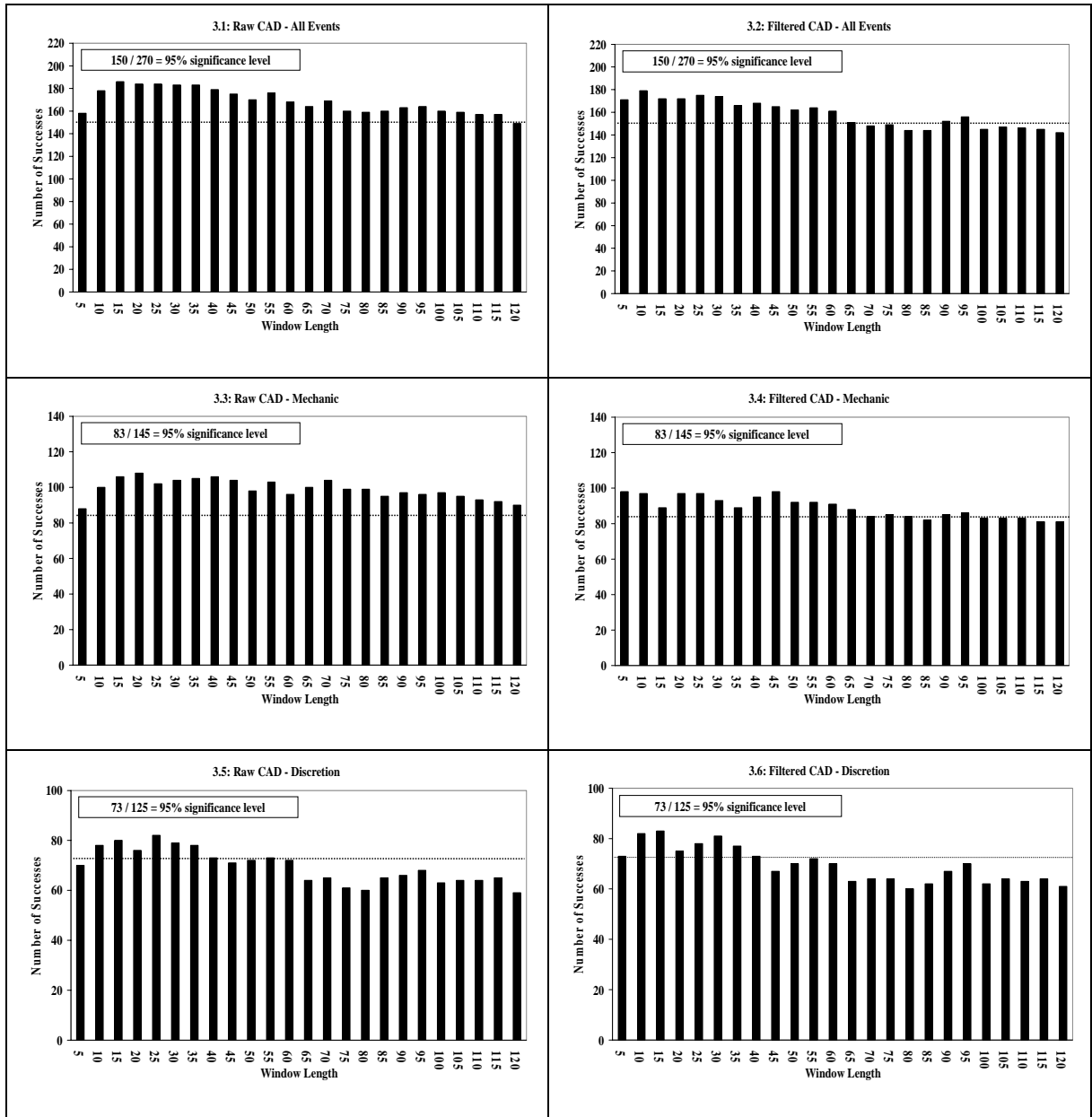


Figure 4: Success of Intervention Based on “Smoothing” Criterion

This figure displays the results of the sign test based on the “smoothing” criterion with the underlying probability parameter of 0.75. Intervention is a success when the CAD/USD rate changes direction consistent with intervention or the rate of change of the CAD/USD decreases following intervention. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all figures 4.1 through 4.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95 percent significance level.

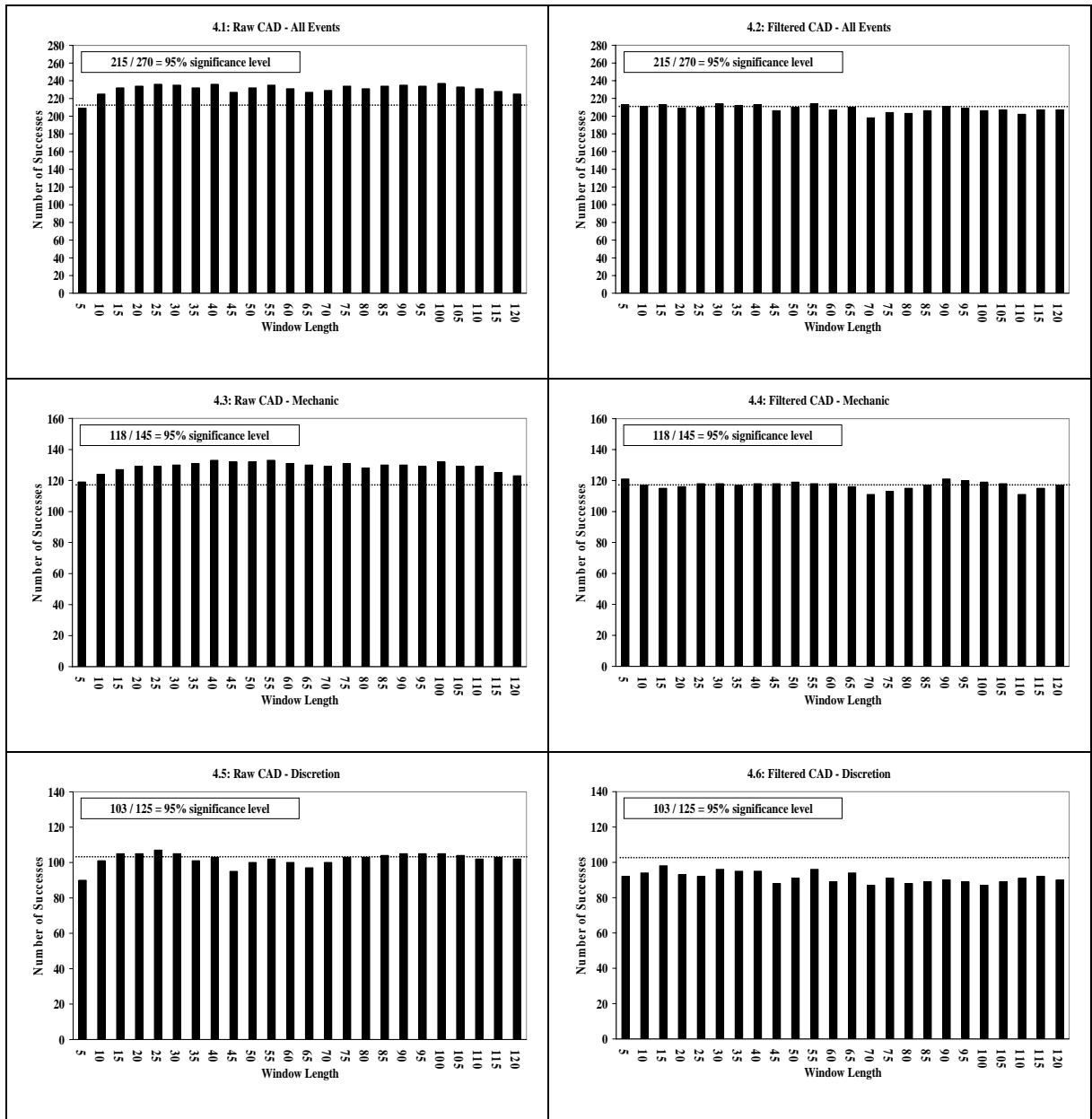


Figure 5: Success of Intervention Based on “Volatility” Criterion

This figure displays the results of the sign test based on the “volatility” criterion with the underlying probability parameter of 0.50. Intervention is a success when volatility decreases from before to after the event. Each column represents the number of successes based on a different window length, ranging from $\frac{1}{2}$ to 2 hours. For all figures 5.1 through 5.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95 percent significance level.

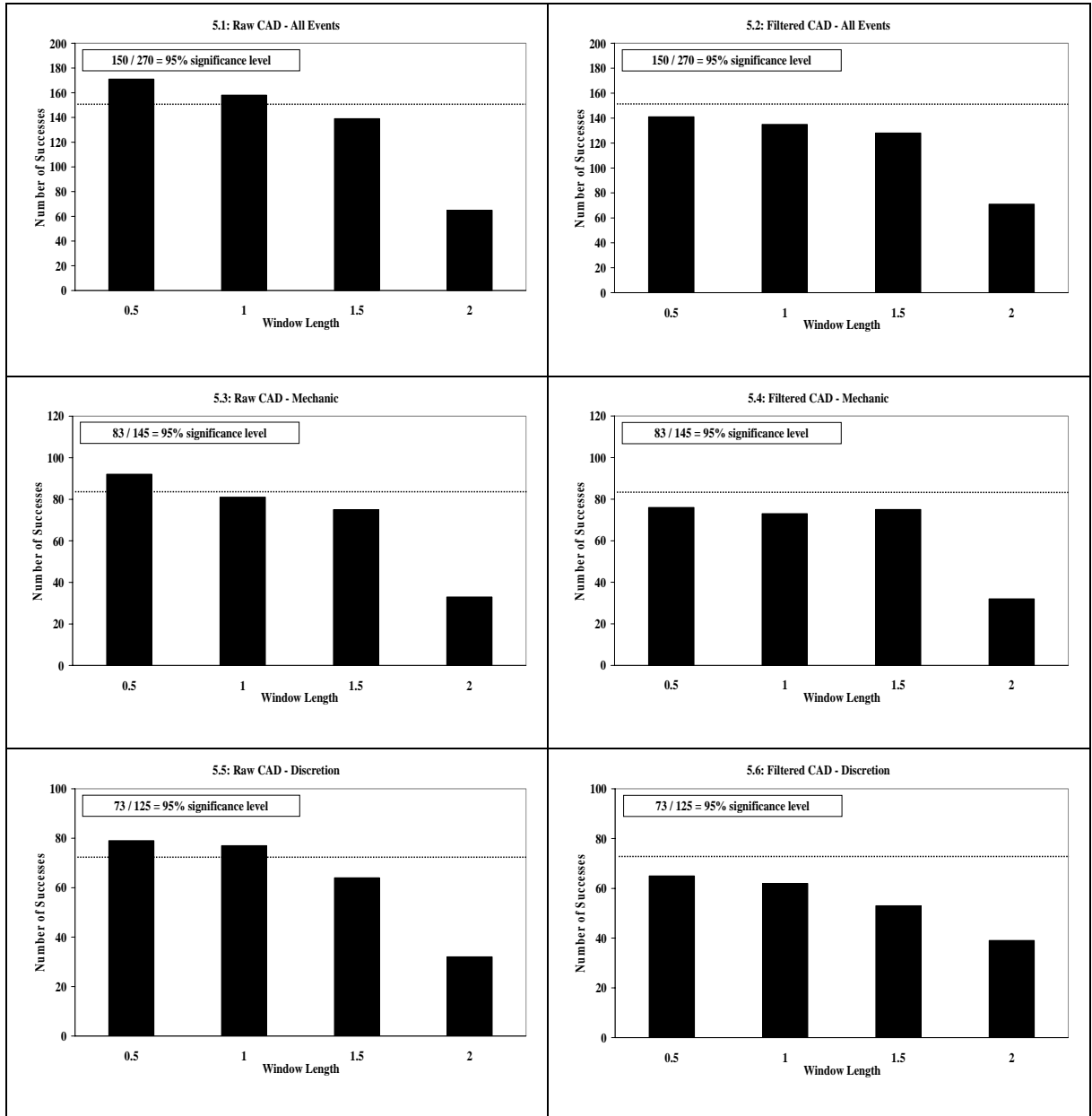


Table 1: Bank of Canada Intervention Transactions, Jan 1995 to Sep 1998

	Number of Intervention Transactions: All	Number of Intervention Transactions: Sell USD	Number of Intervention Transactions: Buy USD
Full Sample	1,530		
Mechanistic	836	444	392
Discretionary	694	688	6
Year: 1995	611		
Mechanistic	611	321	290
Discretionary	0	0	0
Year: 1996	90		
Mechanistic	41	28	13
Discretionary	49	49	0
Year: 1997	357		
Mechanistic	184	95	89
Discretionary	173	173	0
Year: 1998	472		
Mechanistic	0	0	0
Discretionary	472	466	6

Note:

Official Bank of Canada intervention data as well as the classification of intervention transactions carried out in accordance with either the mechanistic or the discretionary intervention framework provided by the Bank of Canada.

Table 2: Intervention and BoC Monetary Policy Changes

Date	Direction: Purchase (P) or Sale (S) of USD	Change in overnight rate target	Overnight rate target after change
10-Jan-95	S	0.50	6.00
12-Jan-95	S	0.50	6.50
17-Jan-95	S	0.50	7.00
16-Feb-95	S	0.50	8.00
10-Jul-95	P	-0.25	6.75
28-Aug-95	P	-0.25	6.25
31-Oct-95	P	-0.25	6.00
25-Jan-96	S	-0.25	5.50
18-Apr-96	S	-0.25	4.75
12-Dec-97	S	0.50	4.25
30-Jan-98	S	0.50	4.75
27-Aug-98	S	1.00	5.75

Note:

No intervention day coincided with a change in US monetary policy.